How to Buy an Energy-Efficient Water-Cooled Electric Chiller

Energy Efficiency and Renewable Energy
Federal Energy Management Program

Why Agencies Should Buy Efficient Products

- *Executive Order 13123 and FAR section 23.704 direct agencies to purchase products in the upper 25% of energy efficiency, including all models that qualify for the EPA/DOE* ENERGY STAR® *product labeling program.*
- *Agencies that use these guidelines to buy efficient products can realize substantial operating cost savings and help prevent pollution.*
- *As the world's largest consumer, the federal government can help "pull" the entire U.S. market towards greater energy efficiency, while saving taxpayer dollars.*

Federal Supply Source:

- General Services Administration (GSA)
Phone: (817) 978-8370

For More Information:

- DOE's Federal Energy Management Program (FEMP) Help Desk and World Wide Web site have up-to-date information on energy-efficient federal procurement, including the latest versions of these recommendations.
Phone: (800) 363-3732
www.eere.energy.gov/femp/procurement
- Green Seal certifies chillers that meet this recommendation's energy efficiency guidelines, as well as other environmental criteria.
Phone: (202) 872-6400
www.greenseal.org
- American Council for an Energy-Efficient Economy (ACEEE) publishes the *Guide to Energy-Efficient Commercial Equipment*, which includes a chapter on HVAC systems, as well as a listing of chiller models that meet this Recommendation.
Phone: (202) 429-0063
www.aceee.org
- ASHRAE publishes the *Cooling and Heating Load Calculation Manual*.
Phone: (800) 527-4723
www.ashrae.org
- Air-Conditioning & Refrigeration Institute (ARI) publishes standards and directories for chillers and other air-conditioning equipment.
Phone: (703) 524-8800
www.ari.org
- E SOURCE publishes the *Electric Chillers Buyer's Guide*.
Phone: (303) 440-8500
www.esource.com
- Lawrence Berkeley National Laboratory's "Cool $ense" Web site has a variety of resources to help in combining building retrofits with chiller replacements.
ateam.lbl.gov/coolsense
- Lawrence Berkeley National Laboratory provided supporting analysis for this recommendation.
Phone: (202) 646-7950

Efficiency Recommendation[a]

Compressor Type and Capacity	Part Load Optimized Chillers: Recommended IPLV[b] (kW/ton)	Part Load Optimized Chillers: Best Available IPLV (kW/ton)
Centrifugal 150 – 299 tons	0.52 or less	0.47
Centrifugal 300 – 2,000 tons	0.45 or less	0.38
Rotary Screw ≥ 150 tons	0.49 or less	0.46

Compressor Type and Capacity	Full Load Optimized Chillers: Recommended Full-Load (kW/ton)	Full Load Optimized Chillers: Best Available Full-Load (kW/ton)
Centrifugal 150 – 299 tons	0.59 or less	0.50
Centrifugal 300 – 2,000 tons	0.56 or less	0.47
Rotary Screw ≥ 150 tons	0.64 or less	0.58

a) Depending on the application, buyers should specify chiller efficiency using either full-load or integrated part-load values as shown (see text.)

b) Values are based on standard rating conditions specified in ARI Standard 550/590-98.

Definitions

Full-load efficiency is measured at peak load conditions as described in ARI Standard 550/590-98.

Integrated Part-Load Value (IPLV) is a weighted average of efficiency measurements at various part-load conditions, as described in ARI Standard 550/590-98. These weightings have changed substantially from the previous standard, ARI 550-92, lowering IPLV ratings by 10-15% for the same equipment.

The decision to specify chiller performance using full-load or part-load efficiency (kW/ton) levels depends upon the application. Part-load (IPLV) is preferred for more variable loads accompanying variable ambient temperature and humidity, the more common situation. Full-load is appropriate where chiller load is high and ambient temperature and humidity are relatively constant (e.g., for baseline chillers). To further optimize your selection, compare chillers based on non-standard part load value (NPLV), which maintains the same weightings

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as IPLV, but allows the designer to prescribe other critical variables (entering condenser water temperature, evaporator leaving water temperature, flow rates, etc.). Proper determination of NPLV is described in ARI 550/590-98.

Where to Find Energy-Efficient Chillers

The General Services Administration (GSA) has a Basic Ordering Agreement (BOA) which offers a streamlined procurement method for chillers based on lowest life-cycle cost. For more information, call GSA at the number listed (see “Federal Supply Source”). For chillers purchased through commercial sources, the BOA can still be used as a guide in preparing specifications, as can ARI and ASHRAE sources (see “For More Information”).

An Energy Savings Performance Contract (ESPC) is an innovative method of financing a new chiller, as well as other associated energy conservation measures, with payments based on energy cost savings. For more information on ESPCs, call the FEMP Help Desk at (800) 363-3732.

Environmental Tips

Refrigerants with ozone-destroying chlorofluorocarbons (CFCs) were common in older chillers but are no longer used in new equipment. The 1992 Montreal Protocol banned the production of CFCs in the US, beginning in 1996. Much of today's equipment uses hydrochlorofluorocarbon (HCFC) refrigerants, which have a much lower ozone-depleting effect. There are also many energy-efficient chillers on the market that use hydrofluorocarbon (HFC) refrigerants, with no ozone-depleting effect. When purchasing an HCFC chiller, buyers can request that the manufacturer conduct leak testing before shipment: leakage of 1% annually is considered good for new equipment (consult Green Seal, listed in “For More Information”).

Owners and operators of chillers with CFCs are faced with three options: 1) continue to operate their chillers with CFCs, which exposes them to the high cost of obtaining the refrigerant from a dwindling reclaimed supply; 2) convert the chillers to use a non-CFC refrigerant, which usually results in some loss in cooling capacity (see “Sizing,” below); or 3) replace the equipment, which requires a substantial capital outlay. These options should be evaluated using life-cycle cost analysis (call the FEMP Help Desk at (800) 363-3732 to obtain LCC analysis materials). It is important when considering the continued operation of chillers with CFCs to assess the process of refrigerant recovery, followed by recycling or reclamation, and to factor in the likely increase in the cost of obtaining replacement CFCs.

When retiring a chiller that contains CFCs or HCFCs, the Clean Air Act requires that the refrigerant be recovered on-site by a certified technician (for information call 800-296-1996).

Early Replacement

Many facility managers are opting for early replacement of older chillers with high efficiency units using non-CFC refrigerants. Good candidates for early retirement are CFC-based chillers with poor efficiencies or histories of high maintenance cost. Energy cost savings can add to the environmental benefits of non-CFC refrigerants. For example, replacing a 500-ton CFC chiller (0.85 kW/ton efficiency) with an efficient (0.56 kW/ton) non-CFC chiller can save $17,000/year, assuming a conservative 6¢/kWh. In some cases demand charge savings may substantially increase this amount. Additionally, some utilities offer financial incentives for replacing inefficient chillers.

Sizing

When choosing a chiller, careful attention to appropriate sizing is critical for achieving maximum energy savings. Many existing units are oversized. An oversized chiller not only costs more to purchase, it cost more to operate due to substantial energy losses from excessive cycling. Use the referenced ASHRAE calculation procedure (see “For More Information”) to determine the cooling load properly. It is often cost-effective to combine chiller replacement with other measures that reduce cooling load, permitting installation of smaller equipment (see “Integrated Chiller Retrofits,” below).

Replacing a single chiller with two or more smaller chillers to meet varying load requirements may be cost-effective. “Parallel staging” of multiple chillers is a common method of meeting peak load in larger installations. Multiple chillers also provide redundancy for routine maintenance and equipment failure. For many typical facilities, sizing one chiller at one-third and another chiller at two-thirds of the peak load enables the system to meet most cooling conditions at relatively high chiller part-load efficiencies. These staged units can also be sized optimally for different conditions. For example, one chiller could be optimized for peak efficiency at summer conditions (85°F condensing water) and the other chiller could be optimized for winter conditions (75°F condensing water).

Integrated Chiller Retrofits

An integrated chiller retrofit can provide enormous energy savings. It combines the chiller replacement or a refrigerant change-out with other energy conservation measures that reduce the cooling load or increase the efficiency of the cooling system itself. Examples of cooling system efficiency improvements are control system upgrades and increased cooling tower capacity. Cooling load reduction measures include tightening the building envelope, and updating lighting systems. The additional cost of these and other load reduction measures can be significantly offset by the savings realized from downsizing the chiller. Lawrence Berkeley National Laboratory's "Cool $ense" project provides guidance on integrated chiller retrofits (see "For More Information").

The first step in implementing an integrated chiller retrofit is a preliminary energy audit to assess the savings potential of various efficiency measures. A preliminary audit can often be provided by energy service companies, architecture and engineering firms, or utilities. FEMP can also provide this technical support, on a reimbursable sub-contract basis. For information, contact FEMP's Technical Assistance Team at (202) 586-5772.

Chiller Cost-Effectiveness Example

Centrifugal Chiller - 500 tons			
Performance	Base Model[a]	Recommended Level	Best Available
Full-Load Efficiency (kW/ton)	0.68	0.56	0.47
Annual Energy Use	680,000 kWh	560,000 kWh	470,000 kWh
Annual Energy Cost	$40,800	$33,600	$28,200
Lifetime Energy Cost	$570,000	$470,000	$400,000
Lifetime Energy Cost Savings	–	$100,000	$170,000
Rotary Screw Chiller - 250 tons			
IPLV Efficiency (kW/ton)	0.78	0.49	0.46
Annual Energy Use	390,000 kWh	245,000 kWh	230,000 kWh
Annual Energy Cost	$23,400	$14,700	$13,800
Lifetime Energy Cost	$330,000	$205,000	$195,000
Lifetime Energy Cost Savings	–	$125,000	$135,000

a) The efficiencies of the base models are just sufficient to meet ASHRAE Standard 90.1.

Definition

Lifetime Energy Cost is the sum of the discounted value of annual energy costs, based on average usage and an assumed chiller life of 23 years. Future electricity price trends and a discount rate of 3.4% are based on federal guidelines (effective from April, 2000 to March, 2001).

Cost-Effectiveness Assumptions

The annual energy use for the centrifugal chiller example is based on 2,000 equivalent full-load hours per year for a 500 ton chiller. The rotary screw chiller example uses a 250 ton machine operating for 2,000 equivalent full-load hours per year at part-load (IPLV) efficiency, since rotary chillers are often installed in applications with variable load conditions. The assumed electricity price is 6¢/kWh, the federal average electricity price (including demand charges) in the US. Since this average cost figure does not incorporate the disproportionately large portion of demand costs that chillers usually contribute, actual cost savings may be greater.

Metric Conversion

1 ton (cooling capacity)
= 12,000 Btu/h
= 3.517 kW

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Understanding the Cost-Effectiveness Table

In the first example shown above, a 500-ton centrifugal chiller with a full-load efficiency of 0.56 kW/ton is cost-effective if its purchase price is no more than $100,000 above the price of the base model. The best available centrifugal model, with an efficiency of 0.47 kW/ton, is cost-effective if its price is no more than $170,000 above the price of the base model. Similarly, in the second example, the 250-ton recommended and best available rotary screw chillers are cost-effective if their respective purchase prices are no more than $125,000 and $135,000 above the price of the base model.

How Do I Perform a Life-Cycle Cost Analysis for My Situation?

The basic formula for estimating a chiller's annual energy use multiplies the average system load (in tons) by the relevant efficiency (full-load or IPLV) by the annual number of equivalent full- or part-load operating hours. The resulting annual kWh figure can then be multiplied by the average cost per kWh for electricity, yielding the annual energy cost:

Annual Energy Cost = Avg. Load * Efficiency * Operating Hours * Electricity Rate.

For full life-cycle cost (LCC) analysis, this annual energy cost should then be multiplied by the regional electricity Uniform Present Value (UPV) factor for the estimated lifetime of the equipment, and then added to the initial cost of the chiller (or present value of the chiller's financed cost):

Life Cycle Cost = (Annual Energy Cost * Uniform Present Value Factor) + Initial Cost.

Note that this simplified formula excludes operation and maintenance costs because they were assumed to be equal. Therefore it does not represent a true LCC calculation. If the operation and maintenance cost of the base and recommended models are substantially different the buyer should include these in the LCC calculation in order to get a truer picture of the potential savings. A manual with the appropriate UPV factors ("Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis"), as well as an LCC analysis guidebook (NIST Handbook 135, "Life-Cycle Costing Manual for the Federal Energy Management Program") and LCC software (BLCC) are all available through the FEMP Help Desk, at (800) 363-3732.

A large proportion of chiller energy costs is often attributable to demand (kW) charges. To incorporate demand and ratchet charges into the cost estimation of chiller options, the ERATES software is also available from the FEMP Help Desk. Rate schedules from ERATES can be imported by the BLCC program, enabling much more accurate estimates of life-cycle costs.

FEMP provides a Web-based chiller calculator tool that simplifies the energy and cost comparisons between chillers with different efficiencies. Go to www.eere.energy.gov/femp/procurement/le_chiller.html, and click on the "Cost-Effectiveness Example."

Definition

A Uniform Present Value factor is the multiplier that incorporates a discount rate, as well as any projected fuel or resource price changes, and allows the simple estimation of life-cycle costs or benefits (given a fixed annual cost or benefit figure and an expected product lifetime).